RoboCupRescue - Robot League Team
IUB Rescue, Germany

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Abstract. The 2006 IUB rescue robot team is described in this paper. The team is active since 2001 in RoboCup rescue. It has competed in five RoboCup real rescue competitions so far. The team takes an integrated approach to rescue robots, i.e., developing the systems from the mechatronics to the high-level functionalities for intelligent autonomous behavior. Based on the development of rugged robots that can handle rough terrain last year, the current team activities focus on improved intelligent autonomous behaviors.

1 Introduction

IUB robotics is working in the domain of rescue robots since 2001. The team has already participated in the real robot rescue league at RoboCup 2002 in Fukuoka (4th place), RoboCup 2003 in Padua (4th place), American Open 2004 in New Orleans (2nd place), RoboCup 2004 in Lisbon and RoboCup 2005 in Osaka [BCC+06] [Bir05] [BCK04] [BKR+02].

The team works toward autonomous intelligent systems that are fieldable. Therefore, an integrated approach is taken, i.e., the systems are developed at IUB from the mechatronics level to the high-level software. The newest robot design is the the so-called rugbot type (figure 1), which reflects this philosophy with its locomotion capabilities while having a significant potential for on-board intelligence. At the RoboCup 2005 competition in Osaka, the IUB team was the only participant that managed to run with a single type of robot in the locomotion as well as in the autonomy challenge.

2 The Robot Hardware

The ”Rugbot” type of robot (figure 1) is the latest development from IUB robotics. The early prototypes have already been used in the RoboCup 2005 competition in Osaka [BCC+06]. The robot is a complete in-house development designed especially for rescue applications [BC06]. The implementation is based on the CubeSystem, a collection of hardware and software components for fast robot prototyping [Bir04a,BKW00]. The

Fig. 1. Two Rugbots in the IUB rescue arena (left) and at the RoboCup competition in Osaka (right).

CubeSystem consists of the RoboCube controller hardware [BKW98], a special operating system called CubeOS [Ken00] and libraries for common robotics tasks [BKS02].

The Rugbots are tracked vehicles. They are lightweight (about 35 kg) and have a small footprint (approximately 50 cm x 50 cm). They are very agile and fast in unstructured environments and they also perform well on open terrain. This holds for tracked vehicles in general [Har97][Won01], which can also be seen by their popularity in the RoboCup rescue league, for example in the robots of Team Freiburg, Robhaz, Casualty or IRL [KSD+06] [LKLP06] [KKP+06] [TT06]. A special feature of rugbot is an active flipper mechanism (figure 2) that allows to negotiate rubble piles and stairs (figure 3). Rugbots have significant computation power in form of an onboard PC and they can be equipped with a large variety of sensors.

3 Control Method and Human-Robot Interface

The software architecture on the robots is designed to support the whole range from teleoperation to full autonomy [BK03]. A single operator can control all robots working in parallel. The robots are semi-autonomous in the default mode. The operator is assisted by various autonomous functionality, especially map-building and identification of victims. The robots can also be run in full autonomous mode as demonstrated at RoboCup 2005 in the autonomy challenge.

For the human robot interface work has been done to enable a single first responder to operate a whole set of robots [BP06]. For this challenge, it is important to preprocess and streamline the immense data flow from the robots and to assist the operator as much as possible in the processes of controlling the robots. Therefore, an adaptive graphical interface is investigated that supports adjustable autonomy of rescue robots. In addition to providing standard interfaces in a flexible and dynamic way, it allows special features like a 3D display and change of viewpoints of 2D map data (figure 4).

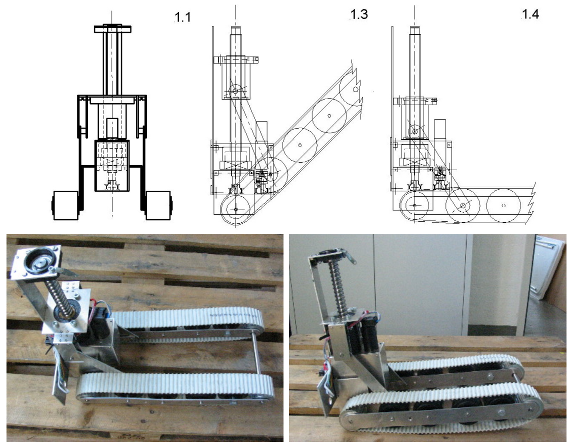

Fig. 2. The support flipper of Rugbot is based on a special ball screw design that can take large forces.

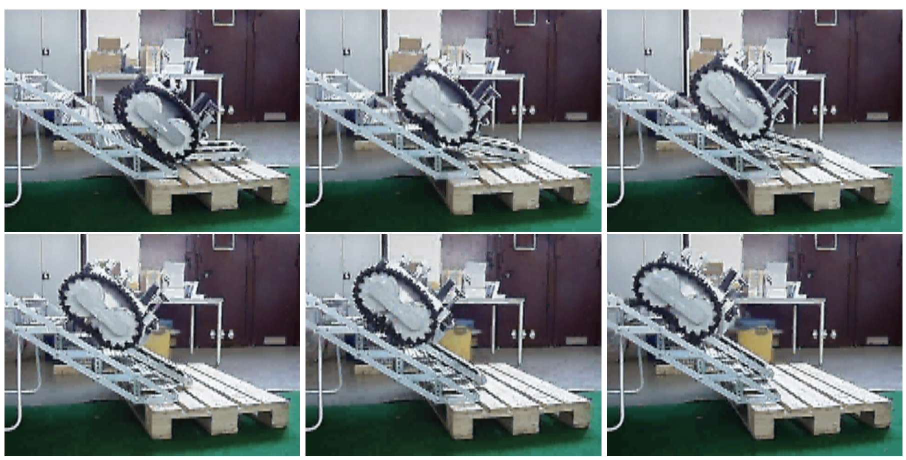

Fig. 3. Rugbot going up stairs.

4 Map generation

Maps are completely autonomously generated on the IUB robots [BC06]. In the default versions, the maps are based on probabilistic occupancy grids. The latest work includes results from successful mapping of large areas with multiple robots [BCed] [CBJ05]. The investigation of multi robot aspects is also done in research on exploration under the constraints of wireless networking [RB06] [RB05].

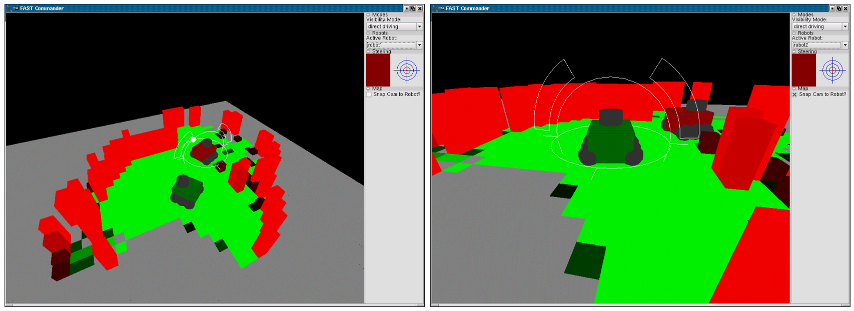

Fig. 4. An example of the 3DViewGUI of map data, where it is possible to either have a free moving camera (left) to get an overview or to snap the camera view to a robot (right).

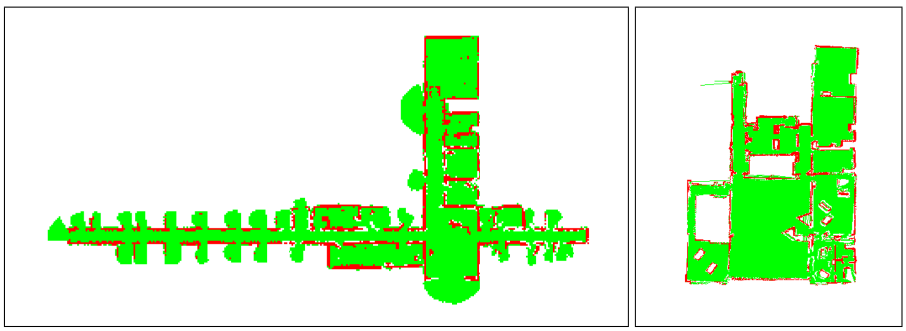

Fig. 5. Two maps of large buildings generated by multiple robots. On the left, a map from 6 robots running in simulation. On the right, a result based on the real world data of 4 robots.

5 Sensors for Navigation and Localization

The robots were previously equipped with a low-cost laserscanner from Hokuyo Automatic, the PB9-11. For some of them a transition has been made to a newer model from Hokuyo, the URG04-LX. These laserscanners are the main range sensors. In addition, several one-dimensional obstacle sensors are available, namely coarse range Ultrasound Sensors from Polaroid with a long range, i.e., up to 10 m and a wide scan angle of 60 deg. Furthermore, high precision Ultrasound Sensors from Baumer Electric with a medium range, i.e., up to 7 m, and a narrow scan angle of 10 deg are used. Finally, active InfraRed Sensors from Sharp with a short range, up to 0.7 m, and narrow scan angle of 10 deg can be employed.

In previous years, two digital compasses were used. The first one is based on the Philips KMZ51 IC. It has an I2C interface and it is directly connected to the CubeSystem. The second compass is from Honeywell. Its RS232 interface is serviced by the onboard PC. Both compasses are very sensitive to electromagnetic noise, especially from the motors. Hence, the main inclination and orientation sensor is a gyro based MTi from XSens. The motors of the robots are equipped with high resolution quadrature encoders from HP. The software modules of the CubeSystem not only use this data for control, but also for odometry and dead-reckoning to estimate the robot's pose. The according data contains relatively large errors and is subject to drift. But it nevertheless can be used together with other sensor data in estimation processes like Kalman filter.

6 Sensors for Victim Identification

The main sensors for victim detection by a human operator via video are USB cameras from Philips. The cameras are high resolution with 1280x960 pixels. The main advantage of these sensors is that they are low-cost. In the standard configuration, Rugbots are equipped with 3 of these cameras.

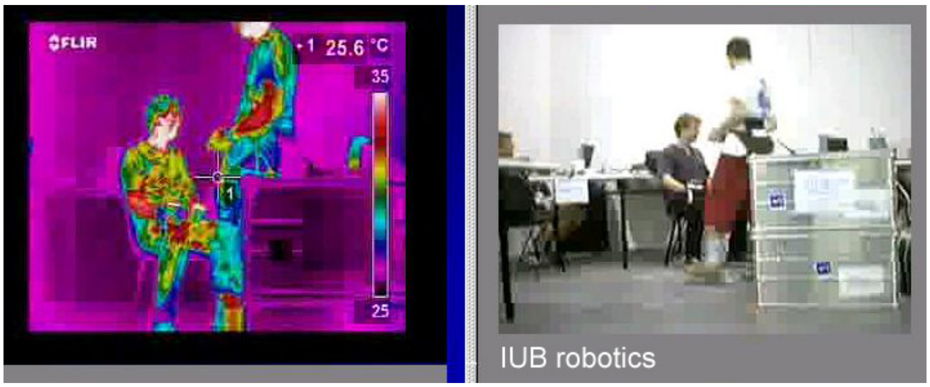

Fig. 6. A typical image from the thermal camera (left) and a normal camera (right).

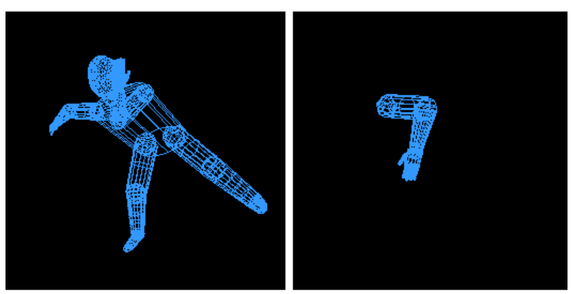

Fig. 7. The 2D rendering of a 3D model of a human and an arm drawn in wireframe mode. The models are used to generate images which are mapped against the therma cam input to detect victims.

A thermal camera is used in addition that not only provides data to the human operator but also to an autonomous vision module for victim detection (figure 6). This Flir

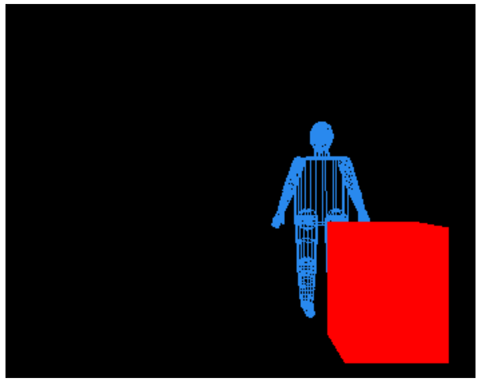

Fig. 8. The output of a sample 3D drawing program. The human is drawn in wireframe mode for illustration purposes. When matching renderings to the thermo-images a uniform color texture is used for humans. Note that most of the time, they boxes have a dark color like the background, i.e., they are at room temperature. These dark boxes are mainly used to represent occlusions.

Fig. 9. The segmented infrared image of a real human in a rather difficult posture and an example rendering of an evolved representation. Though there are a few minor discrepancies between the 2D image and the rendering of the 3D model, the scene is clearly recognized to contain a human.

A20 thermacam has a uncooled, high resolution Focal Plane Array (FPA). Its 160x120 elements provide temperature information in a range of -40^{o}C to 120^{o}C with 0.08^{o}C resolution. The color to temperature map can be changed such that the related image highlights only spots with human body temperature. In our latest work, possible human victims are not only detected by temperature but also by shape.

Concretely, a novel approach to perception is used where a complete 3D scene model is learned on the fly to represent a 2D snapshot. An evolutionary algorithm (EA) generates pieces of 3D code. These are rendered and the resulting images are compared to the current camera picture via a special image similarity function. Based on the feedback of this fitness function, a crude but very fast online evolution generates an approximate 3D model of the environment where non-human objects are represented by boxes. 3D models of humans are available as code sniplets to the EA, which can use them to represent human shapes (figure 7). The code sniplets for 3D boxes are mainly used by the EA to generate representations of occlusions in the scene (figure 8). Successful experiments indicate that even humans in difficult poses can be recognized (figure 9).

Like in previous years, Vaisala CO_2 probes on the robots can be used to detect breathing victims. The main disadvantage of this sensor is it long delay of up to 30 sec in the sensitivity. Last but not least, microphones on the robots can be used by the human operator to identify and to locate victims via sound.

7 Team Training for Operation (Human Factors)

Fig. 10. Robots in the IUB rescue arena.

Since spring 2004, a rescue arena is available at IUB for testing and training purposes [Bir04b]. The arena is based on a high bay racking system (figure 10). This allows to have a large floor-space and many different levels. The arena has a footprint of 5.60m by 4.70m and it is approximately 6m high. It has 3 main floors and several intermediate floors, which are interconnected.

8 System Cost

The costs for each bare robot with control and locomotion system plus on-board PC is in the order of 8,000 Euro. The most expensive single sensor is the Flir A20 therma cam with 16,000 Euro. The standard sensor load of each robot costs in the order of 4,000 Euro. Some detailed information on components and suppliers is located at
`http://robotics.iu-bremen.de/`

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